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DIMETHYL ANTHRANILATE AS A BIRD REPELLENT IN LIVESTOCK FEED

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Depredations at livestock feeding operations by European starlings (*Sturnus vulgaris*), and to a lesser extent by blackbirds (Icterinae), can be a serious economic concern (Besser et al. 1968; Feare 1975, 1980; Glahn 1984). Losses usually result from birds consuming feed (Besser et al. 1968, Feare 1975, Glahn 1984). However, a more significant impact may result from birds acting as carriers of livestock disease (Gough and Beyer 1982). Therefore, a successful control program should reduce both feed consumption and bird populations in the vicinity of feed sites.

Efforts to control birds at livestock feeding operations have relied heavily on the use of lethal control agents such as Starlicide Complete® (1% 3-Chloro-4 methylbenzenamine hydrochloride on poultry pellets) (Purina Mills Co., St. Louis, Mo.). (Use of trade names does not imply government endorsement.) However, recent studies in the Southeast (Glahn et al. 1987) have indicated that because of large roosting populations, resulting high turnover of birds at feed sites may make lethal control impractical for effectively controlling damage.

Twedt and Glahn (1982) outlined management practices that could be implemented at livestock feeding operations to create a suboptimal environment for avian feeding activities. They hypothesized that by substantially reducing the availability of feed palatable to birds, bird numbers at feed sites would necessarily decline. One way to accomplish this is through the use of feeds that are unpalatable or aversive to birds. Such feeds might include additives that are aversive to birds, but palatable to livestock. One candidate additive is dimethyl anthranilate (DMA), a nontoxic food flavoring, which has been shown to be offensive to birds at feed concentrations of 1% active ingredient (a.i.) (Mason et al. 1983). Livestock acceptance tests of feeds treated with 1% DMA have indicated that both cattle and pigs will accept these feeds and perform as well as control groups (G. F. Jones, Western Kentucky Univ., Bowling Green, unpubl. data; R. M. Fisher, U.S. Dep. of Agric., Animal Damage Control, Lebanon, Pa., unpubl. data; D. Williams, Purina Mills Co., St. Louis, Mo., pers. commun.).

A feasibility study with DMA in feedlot settings (Mason et al. 1985) suggested that DMA feed treatments have potential for substantially reducing feed consumption by free-ranging blackbirds and starlings using livestock feeding operations. However, because this study was of short duration and involved small amounts of treated feed adjacent to large quantities of untreated feed, conclusions about DMA for repelling birds were restricted.

Our objective was to evaluate the palatability of DMA to cattle and swine, and its repellency to birds, under actual field conditions. Because all feed offered to livestock and palatable to birds was treated with DMA, the ef-

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fectiveness of this material in repelling birds from feed sites could be assessed.

STUDY AREA AND METHODS

Study Sites

We located test sites in the vicinity of Warren County, Kentucky, in December 1987 with assistance of the county Extension Service and information from various operators, and by visual inspection of livestock operations located by driving county roads. All livestock operators reporting a problem or sites at which >100 birds had been seen were inspected at least twice to ascertain that bird depredations were consistent.

We selected experimental sites on the basis of the following criteria: (1) <100 animals on feed (to reduce DMA needs), (2) ≥100 depredating birds observed on at least 2 occasions before the experiment, (3) capability of the operator to mix DMA with all feed palatable to birds and willingness to expose treatment to livestock and suspend other forms of bird control during the testing period, and (4) separation of sites by ≥4.8 km. Initially, 3 sites met these criteria and were selected for treatment in January 1988. We located a fourth site after initial testing and treated it in February 1988 in a separate trial. Although all experimental sites were separated by ≥4.8 km, they were within 0.3–0.8 km of untreated livestock operations. In addition to experimental sites, we monitored bird activity at 2 reference sites, the Western Kentucky University (WKU) hog lot and the WKU dairy, where no DMA treatments were applied. These sites met criteria (2) and (3) above.

Three experimental sites were hog lots (Hodge, Lawrence, and Bunch), where 0.9–1.8 t of 13–15% protein ground corn/soybean meal ration was fed to 15, 56, and 90 feeder pigs/week, respectively. The fourth site (Prather) was a detached feeding location of a large dairy where 25 Holstein calves were fed an 18% protein calf starter ration mixed with crushed corn at a 50:50 ratio from self feeders. The WKU hog lot and dairy fed 16% protein pelleted hog ration and corn silage to approximately 150 pigs and 150 Holstein dairy cattle, respectively.

Treatment Application

At each experimental site, the feedlot operator was supplied with DMA encapsulated at a rate of 28% (weight by weight) in a food grade starch (Natl. Starch and Chem. Corp., Bridgewater, N.J.). The starch was preweighed and mixed with livestock feed components to yield a feed containing 1% DMA.

Methods of treatment application and livestock feeding varied from site to site. At Lawrence and Prather, tractor-powered feed grinders (New Holland No. 354) were used to mix DMA-starch into the ration as shelled corn and other feed components were ground; sufficient quantities of material were prepared to last throughout the 6-day treatment period. Prepared feeds at both locations were offered to livestock in self-feeders. At Hodge, DMA-starch was mixed into a ground corn/soybean mixture at the local feed mill. The 0.9 t of prepared feed was piled in an open shed exposed to birds and shoveled out to pigs daily throughout the treatment period.

Following the 1% treatment period at Lawrence, the operator chose to mix 1.1 t of 1% DMA-treated ration 50:50 with a similar amount of untreated ration in a feed grinder to produce a DMA concentration of approximately 0.5%. This feed was then offered to livestock while we continued to monitor bird activity. To obtain more data on the potential of lower treatment application rates, we selected the Bunch site to receive a 0.5% DMA treatment in February following a pretreatment observation period. At Bunch, DMA-starch was mixed into a ground corn/soybean mixture at a local feed mill and offered to pigs in self-feeders.

To verify initial DMA concentration and to study the degradation of DMA in livestock feed, we collected 100-g samples of DMA-treated feed from feeders and storage areas at each of the 3 initial operations treated at 1% DMA on days 1, 3, 5, and 7 after treatment formulation. We used a variable pattern of feed collection at the sites using 0.5% DMA treatment. Control samples were collected at each site before treatment. Samples of feed were frozen after collection and shipped to the National Starch and Chemical Corporation for gas chromatographic assay of DMA content.

Treatment Evaluation

The study design involved monitoring responses of birds at experimental and reference sites during a 6-day pretreatment period followed by a 6-day treatment period. Because treatment was applied late on day 1 at Lawrence, only a 5-day treatment period was used. Post-treatment assessment of bird responses at experimental sites only were monitored approximately twice a week for 2 weeks.

Feed Consumption.—During pretreatment and treatment periods with 1% treated feed, a v-shaped wooden trough (1.8 × 0.4 m) was placed just outside existing fencing at all experimental and reference sites to examine feed consumption by birds. Feed consumption was not monitored after treatment or during the 0.5% treatment trials. Four days before the start of the test, we filled troughs with 22.7 kg of a preferred 18% protein poultry pellet ration to attract birds.

During the 6-day pretreatment period, 4-kg samples of untreated livestock feed were removed from storage at each of the experimental sites daily and exposed in the troughs for approximately 8 hours. During the same period, 4 kg of poultry pellets were exposed at each of the reference sites. At the end of an 8-hour period, we assessed consumption by direct weigh-back of feed.

During the 6-day 1.0% treatment period, 4-kg samples of DMA-treated livestock feed were exposed daily at each of the experimental sites. Untreated poultry pellets continued to be exposed daily at the reference sites. As during pretreatment, we assessed consumption at the end of each day.

For analysis, we converted total daily consumption to kilograms consumed per hour of exposure to correct for instances where all feed was removed by birds before the end of the exposure period. Systematic monitoring of troughs before and after bird observations provided an assessment of the approximate time of feed removal.

Bird Observations.—We collected bird observation data 3 times each day at systematic 3-hour intervals starting between 0730 and 0930 hours and continuing such that each experimental and reference site was sampled for bird activity at approximately the same time each day. These data were collected for 6 days immediately before treatment and 6 days during the 1% DMA treatment. To assess possible carryover effects or reinvasion of 1% DMA experimental sites, we monitored birds at each site approximately twice a week for 2 weeks after the 6-day treatment period.

Bird observations at each experimental and reference site included a visual estimate of flock size by species within 100-m radius of the livestock feed site, and counts of birds by species landing at the feed site during a 30-minute observation period. The feed site was defined as areas within the test site where birds could obtain livestock feed.

We estimated flock size by first viewing the area through binoculars and then walking up to the feed site and counting birds as they flushed from the site. After birds were flushed, the entire feed site was observed from a vehicle parked 5–10 m from the site. Numbers of birds were recorded with a multibank counter for a 30-minute period as they returned to the feed site and categorized as starlings, blackbirds, and other birds. The observation period was timed with a stop watch and began when the first bird landed at the site or at the end of a 10-minute waiting period. The observer also recorded the length of time that human disturbance (i.e., operator working at the feed site) occurred at the feed sites that may have prevented bird use. At the Lawrence and Bunch sites (0.5% treatment), there were only 2 observations/day, scheduled 2–3 times/week, and bird entry data were collected for 20 minutes instead of a 30-minute period.

Data were summarized into mean entries per minute of undisturbed observation at each site per day and mean flock sizes at each site per day. We summarized bird observation data separately for starlings (the predominant species) and all birds combined.

Supplemental Data.—Weather data were collected 2–3 times daily during each observation. We summarized these data as means for each day.

Although there was no way to quantitatively assess palatability of DMA-treated feed to livestock, we obtained qualitative information by questioning operators and by observing behavior of livestock during the pretreatment and treatment periods.

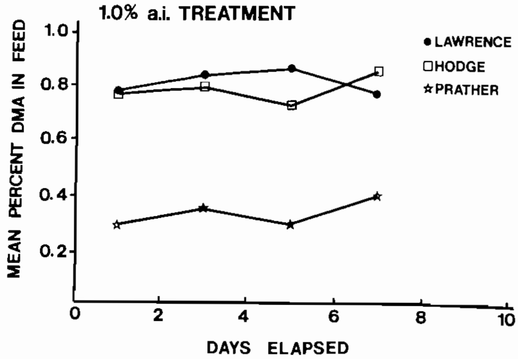

Fig. 1. Dimethyl anthranilate (DMA) in feed sample assays collected at experimental sites in Kentucky, 1988, after formulation at 1.0% treatment levels.

Data Analyses

Because reference sites could not be chosen randomly, direct comparisons of these with experimental sites were not considered valid. Therefore, we compared bird responses at experimental and reference sites separately with a Friedman 2-way nonparametric analysis of variance (ANOVA) (Hollander and Wolfe 1973), comparing testing periods and test sites. This analysis assumed that days were independent and was accomplished by ranking daily measures of bird responses across periods for each experimental and reference site. For analyses of 0.5% unreplicated trials and weather data, we used a Mann-Whitney *U*-test (Hollander and Wolfe 1973) of similarly ranked data to compare differences between testing periods.

RESULTS AND DISCUSSION

DMA Stability in Feed

Chemical analyses of 1% DMA-treated feed samples indicated little reduction in DMA concentrations across sampling dates (Fig. 1). Limited sampling of 0.5% DMA-treated feed suggested similar stability. Comparison of DMA concentrations on the initial sampling date with the expected concentration revealed that sample values were only slightly lower (0.1–0.2% less) than expected. This discrepancy could reflect losses during the mixing process or lack of precision in formulating bulk feeds. The exception to this was the treatment rate at Prather, in which DMA concentrations were less than half the expected concentration. We

Table 1. Average feed consumption (kg/hr of exposure) by birds from troughs excluded from livestock at experimental and reference sites (WKU) in Kentucky, 1988, during pretreatment and treatment periods with 1% dimethyl anthranilate feed treatments.

Sites	Pretreatment		Treatment	
	$\bar{x}$	SE	$\bar{x}$	SE
Experimental				
Hodge	0.423	0.045	0.002	0.002
Prather	0.204	0.036	0.007	0.002
Lawrence	0.015	0.004	0	0
Reference				
WKU Hog	1.057	0.090	1.108	0.020
WKU Dairy	0.289	0.138	0.672	0.076

Table 2. Average starling entries per minute of undisturbed observation at experimental and reference sites (WKU) in Kentucky, 1988, during pretreatment, treatment, and post-treatment periods with 0.5 and 1.0% dimethyl anthranilate (DMA) feed treatments.

Sites	Pre-treatment		Treatment		Post-treatment	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Experimental (1% DMA)						
Hodge	24.6	3.4	0.5	0.1	24.9	5.4
Prather	23.4	5.4	4.4	1.0	27.8	7.1
Lawrence	7.9	2.0	0.3	0.2	8.5	3.0
Experimental (0.5% DMA)						
Lawrence			1.7	0.9	8.5	3.0
Bunch	16.1	2.9	10.5	1.7		
Reference						
WKU Hog	27.7	6.7	11.7	1.3		
WKU Dairy	16.4	7.0	3.9	0.9		

speculate that the DMA concentration at Prather may have been the result of the large particle size of the Prather feed, which may have allowed DMA to separate from feed in the feeder or during collection, shipment, and analysis of samples. Whatever the reason, the treatment regime employed at Prather represented "actual farm conditions," and as such, was considered as having received the 1.0% treatment.

These results suggested that overall DMA could be practically formulated by livestock operators and that DMA in feed is stable under actual farm conditions for at least 7 days. Based on the feed use practices at the operations involved in this study, this stability would be sufficient for DMA to persist throughout the storage life of the feed.

Weather Chronology

Weather conditions varied considerably during this study. Daily temperatures were different ($U = 21$, 1 df, $P = 0.005$) between pretreatment and treatment periods during 1% DMA trials. The pretreatment period was characterized by unusually low temperatures (−2.7 to −10.1 C) and 100% snow cover on 4 of 6 days. Conversely, temperatures during the treatment period were relatively moderate (−2.7 to 8.4 C), and snow was present on only 1 day. This change in weather may have confounded interpretation of the treatment response when comparing the 1% treatment period with that of the pretreatment. Previous studies (Bailey 1966, Stickley 1981, Glahn and Otis 1986) have indicated that weather influences bird activity and feed consumption at feedlots.

A comparison of weather conditions between treatment and post-treatment periods failed to reveal differences ($U = 20$, 1 df, $P = 0.75$). Similarly, there were no differences (Lawrence: $U = 17$, 1 df, $P = 0.70$; Bunch: $U = 17$, 1 df, $P = 0.88$) in weather conditions during the 0.5% treatment trials.

Test Trough Feed Consumption

At the Hodge and Prather sites, birds consumed all 22.7 kg of poultry pellets over the 4-day prebaiting period. At the Lawrence site, however, the test trough had to be placed approximately 100 m away from the feed site, and birds did not start consuming feed from this test trough until 2 days after the start of the pretreatment period. For this reason, only 4 days of pretreatment and 6 days of treatment consumption could be analyzed at this site. Feed consumption per hour of exposure differed between pretreatment and treatment periods at experimental sites ($F = 68.6$, 1 df, $P < 0.001$). Consumption during treatment was

Table 3. Average starling flock sizes recorded at experimental and reference sites (WKU) in Kentucky, 1988, during pretreatment, treatment, and post-treatment periods with 0.5 and 1.0% dimethyl anthranilate (DMA) feed treatments.

Sites	Pretreatment		Treatment		Post-treatment	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Experimental (1% DMA)						
Hodge	145.1	24.5	12.9	5.6	429.5	73.4
Prather	130.8	31.7	96.0	43.1	499.6	108.2
Lawrence	51.1	14.3	3.1	1.4	96.2	19.9
Experimental (0.5% DMA)						
Lawrence			2.2	0.9	96.2	19.9
Bunch	162.5	39.8	98.9	27.6		
Reference						
WKU Hog	727.8	91.3	344.4	38.4		
WKU Dairy	113.8	18.5	34.1	6.9		

nearly eliminated (range = 0–0.01 kg) at these sites (Table 1).

Despite changes in weather conditions, there were no differences (F = 2.6, 1 df, P = 0.12) in consumption rates per hour of exposure at the WKU reference sites (Table 1). Lack of differences may have been partially influenced by the use of poultry pellets at reference sites. Because poultry pellets are a preferred starling food, they may have sustained abnormally high levels of feed consumption. However, because all experimental sites used high protein rations, also highly palatable to starlings, differences in feed consumption responses between experimental and reference sites would appear to be treatment related.

Mason et al. (1985) reported similar reductions in consumption of feeds treated at 0.28 and 0.20% DMA; in their study, however, birds (primarily starlings) had a choice between small amounts of treated feed and large amounts of untreated feed being fed to livestock. In contrast, our results suggest that birds are repelled by 1% DMA in feed when no alternative feed is available.

Bird Observations

At experimental sites there were more bird entries (by starlings [Table 2] and all birds combined) during pretreatment than during treatment (F = 18.6, 1 df, P < 0.001). When treatments were discontinued, numbers of birds returned to or exceeded their original levels. Birds entering reference sites also decreased from pretreatment to treatment (F = 19.2, 1 df, P < 0.001), probably due to changes in weather conditions. Because of the lack of confounding changes in weather between treatment and post-treatment periods, differences (F = 25.5, 1 df, P < 0.001) in bird entries between these periods suggested that overall changes in bird entries were treatment related. Trials at 2 sites incorporating DMA at the 0.5% level both yielded no changes (Bunch: U = 21, 1 df, P = 0.47; Lawrence: U = 9.5, 1 df, P = 0.20) in starling (Table 2) and total bird entries between periods.

Reductions in bird entries in response to 1% treatment further support the reduction in consumption of livestock feed by birds during treatment as bird entries have been shown to be an indirect index of feed consumption (Glahn et al. 1983). Differences in effectiveness of 0.5 and 1.0% DMA treatments agree with concentration effects noted in previous laboratory studies (Mason et al. 1983) and suggest that DMA concentrations need to approach 1% to repel birds under field conditions.

Results of flock size analyses (starlings only [Table 3] and all birds) tended to parallel bird entry data with differences (experimental sites:

$F = 28.3$, 1 df, $P < 0.001$; reference sites: $F = 26.4$, 1 df, $P < 0.001$) between pretreatment and treatment periods for both 1% experimental and reference sites and between treatment and post-treatment periods for 1% experimental sites ($F = 59.6$, 1 df, $P < 0.001$). As with bird entry data, the difference in response between treatment and post-treatment periods supports the contention that DMA treatments (and not weather) caused reductions in birds.

At the 0.5% treatment level, comparisons of treated and untreated periods for flock sizes at the Lawrence and Bunch sites yielded mixed results (Table 3). Although there was a reduction ($U = 6$, 1 df, $P = 0.03$) at the Lawrence site (treatment vs. post-treatment), flock sizes did not differ ($U = 21.5$, 1 df, $P = 0.38$) at the Bunch site (pretreatment vs. treatment). This inconsistency in treatment response may have been due partly to the previous exposure of the 1.0% treatment to birds at Lawrence.

The observed reduction of birds in the vicinity of treated feed sites probably has greater importance than reduction in feed consumption. It supports the hypothesis of Twedt and Glahn (1982) that birds will leave sites where feed palatability is reduced. Reducing bird numbers is also of practical significance for reducing the potential of livestock disease transmission and for obtaining acceptance by livestock producers.

Livestock Response to Treatment

At all 1% DMA experimental sites, both pigs and cattle appeared to exhibit some initial feed rejection in response to treatment, but adjusted to the treatment during the course of the treatment period. At the Prather lot, observations indicated that Holstein calves initially had some aversion to the treated feed on day 1, but appeared to adjust to the treatment over time. The operator also observed some reduction in feed consumption, but felt that other factors may have contributed to this.

Feeder pigs at the Hodge and Lawrence lots also appeared to reject 1% treated feed initially. At the Hodge lot the operator reported a 50% reduction in feed consumption initially, but thought pigs adjusted to the feed over time. At the Lawrence lot, observations indicated that pigs were initially repelled by the feed. Upon coming to feed, pigs lifted each lid on the multiple feeder openings and then started feeding on untreated feed spillage around the feeder or rooted for food in the pasture. This behavior ceased midway during the 1% treatment period, and the operator believed pigs responded well to treatment. This assessment agrees well with preliminary investigations of feeder pig performance with 1% DMA treatments (G. F. Jones, Western Kentucky Univ., Bowling Green, unpubl. data), in which confined pigs fed treated rations for 4 weeks had growth rates and feed efficiencies equal to or exceeding control groups. There was no evidence of feed rejection by feeder pigs receiving 0.5% DMA treatment during the Lawrence or Bunch trials.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

To be practical for use in feedlot settings, a bird repellent feed additive must (1) be readily formulated with various feeds, using available feed processing methods, so that reliable and effective concentrations of active ingredient can be achieved; (2) retain effective levels of active ingredient during storage under actual farm conditions; (3) be palatable to livestock and have no detrimental effects on growth or performance; (4) consistently reduce feed consumption by blackbirds and starlings to the point that these birds leave the feed site to forage elsewhere; and (5) be cost-effective in reducing the collective damage caused by birds at livestock feeding operations.

Based on results of our study, DMA formulated at 1% in livestock feed appears to meet the above criteria for a practical bird repellent. Despite unexpected variation in DMA assay results of feed, operators appeared to be able to use technical material in their feeds to formulate effective DMA concentrations. The active ingredient appeared to be stable through most of the storage life of feeds used in this study.

Despite some initial aversion by livestock to treated feed, our study appeared to confirm preliminary investigations that DMA is palatable to livestock. However, more studies of livestock acceptance and performance are needed to verify these results.

Our results suggested that the effective concentration of DMA in feed is between 0.5 and 1.0%. The 1% level in feed was associated with consistent reductions in feed consumption by birds among experimental sites with corresponding reduction of birds using these sites. There were no residual effects of treatment, and birds quickly returned to sites after treatments were terminated. The close proximity of other untreated feed sites to experimental sites may have influenced the relative ease in repelling birds from experimental sites by providing nearby alternative food sources. Correspondingly, these nearby alternative food sources may have kept birds in close proximity to experimental sites and influenced the rapid reinvasion of experimental sites when treatments were terminated. In contrast, at more isolated feedlots, bird reduction may be more difficult to achieve, but limited treatment may have more long-lasting effects.

Because the treatment regimen for effective control remains undetermined, the cost-benefits of DMA feed treatments remain difficult to project. Furthermore, all aspects of damage costs are difficult to calculate. Based solely on reducing feed losses of relatively low-priced feed ($0.15–0.30/kg), it may be impossible to achieve favorable benefits if treatment costs, grossly estimated at $0.30/kg, must be sustained throughout the entire damage season. However, if in addition to feed losses, other aspects of damage such as fouling of premises and disease transmission are effectively controlled with an intermittent treatment regimen, then favorable cost-benefits may be achievable. Although studies of cost effectiveness of DMA in divergent feedlot settings are warranted, results of this study suggest DMA incorporated into livestock feed at concentrations approaching 1% appears to be an effective avian repellent that has practical application for reducing blackbird and starling depredations at livestock feeding operations.

SUMMARY

Field trials of dimethyl anthranilate (DMA) incorporated at 1.0 and 0.5% active ingredient as a bird repellent in livestock feed were conducted at livestock farms in Kentucky in January and February 1988. Trials were conducted to examine formulating methods and stability of DMA in livestock feed, livestock response to treatment, and bird response to treatment with respect to feed consumption and feed site avoidance. Results of chemical analysis of feed indicated that formulating methods were adequate and that DMA remained stable in stored feed for ≥1 week. Feeder pigs and Holstein calves showed an initial aversion to 1% DMA-treated feed, but appeared to adjust to treatment over several days.

Although there were significant differences in feed consumption by birds during 1% DMA trials, estimates of bird activity at feed sites may have been confounded by weather changes between pretreatment and treatment assessment periods. Subsequent increases in bird use of feed sites between treatment and post-treatment periods suggested that bird responses were treatment related. There were no conspicuous changes in livestock or bird response to the 0.5% DMA treatments, suggesting that the field effective concentration of DMA is between 0.5 and 1.0% active ingredient. Despite short-term livestock feed rejection, DMA as a livestock feed additive at concentrations approaching

1% appears to be an effective repellent for blackbirds and starlings.

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